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RADIOMETRIC AND SPECTRAL MEASUREMENT INSTRUMENTS

CRANE DIVISION
NAVAL SURFACE WARFARE CENTER
ORDNANCE ENGINEERING DIRECTORATE
CRANE, IN 47522-5050

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PREPARED FOR:
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13. ABSTRACT (Maximum 200 words)

THIS IS A DESCRIPTION OF AN ASSORTMENT OF RADIOMETRIC AND SPECTRAL INSTRUMENTATION USED FOR MEASUREMENT OF THE RADIATIVE OUTPUT OF ASSORTED DEVICES. THESE INSTRUMENTS ARE INSTALLED AND ROUTINELY OPERATED AT THIS CENTER. THE CONTENTS DESCRIBE SOME OF THE INSTRUMENT PARAMETERS AND MEASUREMENT CAPABILITY.

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BACKGROUND DISCRIMINATING RADIOMETER

The CI Systems Model SR-5100 Background Discriminating Radiometer is used for the measurement of radiant intensity of stationary and moving emissive sources with automatic compensation for background. The system consists of an optical head, an electronic controller and a data acquisition/data analysis system. The device uses a liquid nitrogen cooled InSb detector and operates in the region from 1 - 5 micrometers. The instrument uses reflective fore optics and has a field of view of 1.4 degrees at the 50 percent points. Wavelength selection is done by selecting one of six available regions determined by the appropriate choice of bandpass filters. The system is used at ranges of 0.1 - 5 km. Data are recorded and digitized at 200 - 1000 points/second.

The Background Discriminating Radiometer is designed to provide automatic compensation for changes in the background primarily due to a moving target, e.g., an airplane flying through the air. The compensation is performed by chopping the radiometer input between two different fields of view. These two fields of view are separated horizontally in space. Thus one field of view provides the target signature and the other provides the background. In this way changes in the background can be compensated.

FOUR CHANNEL INFRARED BANDED RADIOMETER

The Mesa, Inc., Model 1004 four channel banded radiometer is designed to simultaneously measure the radiant intensity from emissive sources in laboratory or field conditions. The system consists of an optical head and a data acquisition/data analysis system. The detectors in this system are standard pyroelectric detectors, spectrally flat from 0.2 - 20 micrometers, with bandpass filters to select the appropriate wavelength regions of interest. Each detector has a germanium lens for collecting optics. The device behaves essentially as a pyroelectric radiometer. The field of view of the system can be either 4.5 degrees or 10 degrees at the 50 percent points. Measurements are done at a rate of 50/second.

AGEMA MODEL 880 THERMAL IMAGER

The Agema Model 880 thermal imager is used for the measurement of temperature and/or radiant intensity of remote emissive sources under field conditions at ranges of 0.1 to 1.0 km. Because the unit is an imaging instrument it will be possible to use it for measurement of extended plume sources. The unit consists of a short-wavelength infrared (SWIR) head (InSb) operating from 2 - 5 micrometers, a long-wavelength infrared (LWIR) head (HgCdTe) operating from 8 - 13 micrometers, a dual burst recording unit and associated video monitors. It is a serial scan instrument, providing an interlaced video image for each of two channels at a rate of 6 scans per second. The data is digitally recorded on two high speed Winchester hard disks and a NTSC format video signal is available for recording on standard VHS tape.

The Model 880 system is a calibrated thermal imager. Radiant intensity can be calculated within a given bandpass if range information is known. Currently, the SWIR head is calibrated in the 2.0 - 2.5 and 3.8 - 4.6 micrometer bands. The instrument does not allow simultaneous measurement in these two bands. The LWIR head is calibrated for the total bandpass of this head. The calibration is valid for emissive sources with temperatures up to 1750 degrees C in the 2.0 - 2.5 micrometer bandpass and up to 2000 degrees C in the 3.8 - 4.6 and the 8 - 13 micrometer bandpasses.

OPTICAL MULTICHANNEL ANALYZER (OMA)

The Optical Multichannel Analyzer is a spectroscopic tool used for the measurement of visible and near infrared spectra of remote emissive sources. The instrument consists of an optical head and a controller/data interface. The optical head is a grating spectrograph with a focal plane diode array as the recording device. Depending on the type of focal plane array used and the grating selection the instrument can be used for spectroscopy in the ultraviolet, visible or near-infrared spectral region. The maximum scan rate is 30 spectra/second and the instrument is very useful for collecting spectral time histories.

As currently configured the OMA has no front end optics and was originally designed as a laboratory instrument. It has been used successfully in the field in a limited number of tests in the transient velocity windstream apparatus.

NICOLET 170-RS FOURIER TRANSFORM INFRARED SPECTROMETER

The Nicolet Model 170-RS Fourier Transform Infrared (FTIR) Spectrometer is an interferometer spectrometer designed for the measurement of spectral radiant intensity from emissive sources under laboratory conditions at ranges between 0.01 and 0.10 km. The instrument consists of an interferometer spectrometer head and a dedicated data collection/data analysis system. The Model 170-RS is equipped with a two inch diameter zinc selenide collecting lens and has a 25 mrad field of view.

The Nicolet FTIR uses a conventional design Michelson interferometer. The instrument has a liquid nitrogen cooled HgCdTe detector and a zinc selenide beam splitter and operates from 1.6 - 14 micrometers. It can obtain 6 scans per second at a resolution of 4 cm^{-1}. Resolutions as high as 0.125 cm^{-1} can be obtained with scan times of 7 seconds per scan. Infrared spectra at this resolution have been obtained for illuminating flares. In addition to providing spectral radiant intensity as a function of wavelength over the course of a burn, the instrument software allows the spectrum to be integrated over any spectral band of interest within its wavelength range to provide the same type of radiant intensity versus time plots obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpasses and doing several different bandpasses after each event.

The instrument is ideally suited for higher resolution measurements of research and development type flares in a laboratory type environment to obtain emitter identification and temperature measurements based on rotational fine structure of infrared vibrational bands in diatomic and polyatomic molecules.

NICOLET 5-SXC FOURIER TRANSFORM INFRARED SPECTROMETER

The Nicolet Model 5-SXC Fourier Transform Infrared (FTIR) Spectrometer is an interferometer spectrometer designed for the measurement of spectral radiant intensity from emissive sources under laboratory conditions at ranges between 0.01 and 0.10 km. The instrument consists of an interferometer spectrometer head and a dedicated data collection/data analysis system. The 5-SXC is equipped with a two inch diameter zinc selenide collecting lens and has a 50 mrad field of view. The field of view is expandable to 250 mrad if a convex mirror is substituted for the usual plane collection mirror.

The Nicolet FTIR uses a conventional design Michelson interferometer. The instrument has a liquid nitrogen cooled InSb detector and operates from 1.6 - 5.8 micrometers. A similar liquid nitrogen cooled HgCdTe detector and a zinc selenide beam splitter are available to extend the useful range to 14 micrometers. It can obtain 3 scans per second at a resolution of 4 cm^{-1}. In addition to providing spectral radiant intensity as a function of wavelength over the course of a burn, the instrument software allows the spectrum to be integrated over any spectral band of interest within its wavelength range to provide the same type of radiant intensity versus time plots obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpasses and doing several different bandpasses after each event.

BOMEM MB-100 FOURIER TRANSFORM INFRARED SPECTROMETER

The Bomem Model MB-100 Fourier Transform Infrared (FTIR) Spectrometer is an interferometer spectrometer designed for the measurement of spectral radiant intensity from emissive sources under field conditions at ranges between 0.01 and 2.0 km. The instrument is modular consisting of an interferometer spectrometer head, a dedicated signal processor board and a data collection/data analysis system. The MB-100 is equipped with a gathering telescope with a field of view of 28 mrad.

The Bomem FTIR uses a unique 'wish-bone' design of a Michelson interferometer. The instrument has a liquid nitrogen cooled InSb detector and operates from 1.6 - 5.8 micrometers. It can obtain 3 scans per second at a resolution of 4 cm^{-1}. In addition to providing spectral radiant intensity as a function of wavelength over the course of a burn, the instrument software allows the spectrum to be integrated over any spectral band of interest within its wavelength range to provide the same type of radiant intensity versus time plots obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpasses and doing several different bandpasses after each event. The instrument is compact and is designed to be a field portable instrument.

CIRCULAR VARIABLE FILTER (CVF) SPECTRORADIOMETER

The CVF spectroradiometer is a multi-purpose instrument designed for the measurement of spectral radiant intensity of emissive sources under field conditions at ranges of 0.5 - 5.0 km. The instrument is modular, consisting of four major components. It is equipped with a 4" silicon/germanium lens collecting optics, uses a liquid nitrogen cooled InSb detector and has a total field of view of 1.5 degrees (90% response).

The CVF uses a spinning circular variable filter for wavelength separation. It has a wavelength range of 1.8 to 5.4 micrometers with a spectral resolution of 0.03 micrometers and can scan its complete spectral range at a rate of 15 scans/second. In addition to providing spectral radiant intensity as a function of time the software in the CVF allows the spectrum to be integrated over any spectral band of interest within its range to provide the same data as obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpass or doing several bandpasses after the event.

RADIOMETRIC TEST FACILITY

The Radiometric Test Facility (RTF) has been in use for many years for development and lot acceptance testing of a variety of pyrotechnic devices including decoy flares, illuminating flares, tracking flares and colored signals. The RTF consists of a burning chamber, a tunnel and two adjacent rooms for instrumentation. The burning chamber in the RTF is 3 meters x 3 meters x 5 meters. The tunnel in the RTF is 2 meters wide by 60 meters long.

In the RTF the air flow for removal of combustion products is from top to bottom. The direction of the air flow was designed in this way to allow the testing of large aircraft parachute illuminating flares that were burned face down to simulate end use. Burning face down with an upward air flow did not provide an accurate representation of the flare output. The combustion products are exhausted through a bag house equipped with filters to remove any solid particulate before release to the atmosphere.

In the RTF the effect of a decoy flare being ejected from an aircraft is simulated by a windstream blowdown apparatus. This apparatus is a 500 gallon reservoir tank that delivers a high velocity air stream through a converging-diverging nozzle system and four inch delivery tube. The air flow through the nozzle system is controlled by a gate valve assembly. When the test is performed an electrical signal causes solenoid valves to actuate to open the gate valve and initiate the igniter assembly on the flare. The air flow from the simulator is parallel to the floor and perpendicular to detector line of sight. The flare grain longitudinal axis is perpendicular to the air flow and the center of the grain is 53 cm from the end of the apparatus. Because of the nature of the exhaust air removal system in the RTF the air stream simulator and the flare grain are located between the detectors and the exhaust air system. The air stream blows the combustion products across the burning chamber to a deflector that steers the combustion products behind the burning flare and into the exhaust air flow.

A variety of instrumentation can be used in the RTF. In addition to measuring the radiometric output using pyroelectric radiometers, photometers can be used can be used to measure the visible output and colorimeters can be used to obtain the dominant wavelength and color purity of devices. It is also possible in this facility to collect spectral information in the wavelength regions from 0.25 micrometers to 14 micrometers using grating spectrographs, a circular variable filter spectrometer and Fourier transform infrared spectrometers. Absolute measurements can be made by calibrating the instrumentation against known NIST standards before and after testing.

TRANSIENT VELOCITY WINDSTREAM APPARATUS

The transient velocity windstream apparatus is a free jet expansion windstream apparatus designed to provide adjustable air velocity versus time profiles to simulate the launch of decoy flares from a moving aircraft. The outdoor apparatus consists of several air compressors, a bank of air storage tanks, a computer controlled valve to control air flow and a nozzle. The device is capable of producing air flows from 0.1 to 0.9 Mach at either a constant velocity or, under computer control, a variable velocity versus time profile. The variable profiles can be adjusted to simulate the observed velocity versus time behavior experienced by a decoy flare when ejected from an aircraft. Run times from 10 to 90 seconds can be obtained depending on the initial velocity chosen.

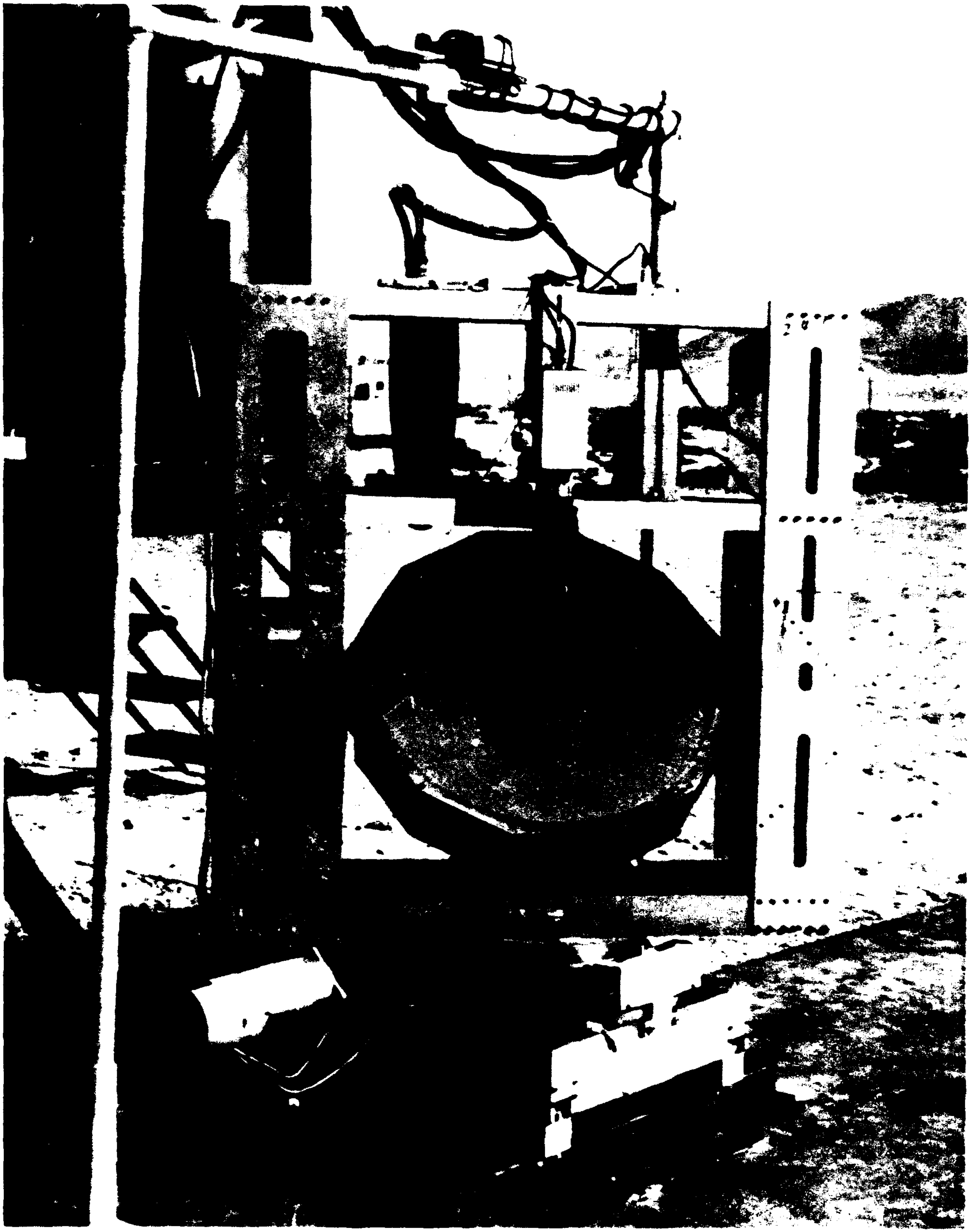
In a typical experiment a decoy flare is positioned in front of the nozzle of the apparatus. A programmed velocity versus time blowdown is initiated and the flare is ignited at the appropriate velocity. Radiant intensity and spectral radiant intensity are then measured. Instrumentation used includes pyroelectric radiometers equipped with appropriate bandpass filters to select the wavelength region of interest, InSb radiometers with various filters, the circular variable filter spectrometer, grating spectrographs with focal plane array detectors and Fourier transform infrared spectrometers. Measurement distances of 30 meters, 80 meters and 500 meters are typically used. Because of the nature of the test apparatus it is possible to obtain the angular distribution of radiant intensity from 10 - 300 degrees at several different angles simultaneously.

AUTOMATED VIDEO/IR TRACKING SYSTEM

The automated video/IR tracking system is a mobile system for testing the effectiveness of infrared countermeasures against captive missile seekers in an "endgame" scenario, i.e., the portion of flyout in which the missile has solved the proportional navigation equation and is on an intercept course. This simulation provides an excellent indicator of the overall effectiveness of an infrared countermeasure as a function of range and aspect angle.

The prominent feature of the system is a two axis table and controller. Similar in function to equipment used in computer controlled machining operations, the table consists of a large equipment rack mounted to the azimuthal axis and a 27 inch diameter front surface mirror mounted to the elevational axis. All measurement equipment is mounted vertically, looking downward into the mirror. Two missile seekers and two video cameras may be mounted in this fashion. In a test scenario the mount pivots about the table to track the target horizontally while the mirror tilts to track the target in the vertical direction. Targets with horizontal velocities of up to 15 degrees/second (650 ft/sec at 2500 feet range) may be tracked with this system. Since the angular forces exerted on the seekers during target tracking are minimized, the endgame scenario is realistically simulated. Mount movement can be controlled using a hand operated joystick, a video image tracker or an infrared tracker. Video tracking is preferred to provide the smoothest track while keeping the target centered in the seeker field of view.

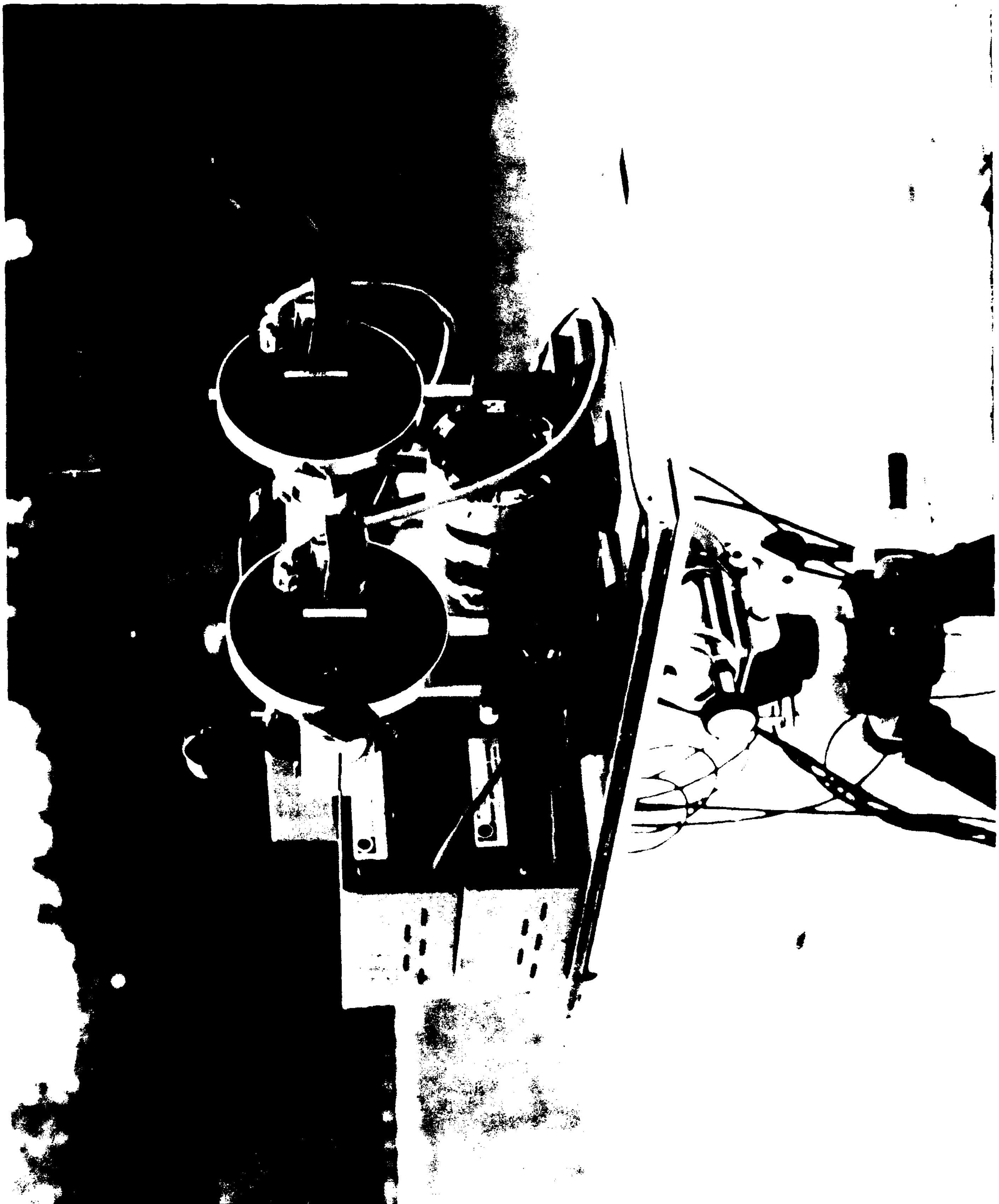
Seeker signals are monitored and recorded during tests to provide a picture of what the seeker was "thinking" at the time of the countermeasure event. Gyro movement, which indicates whether the seeker is tracking a target or decoy, is superimposed over a video image from the tracking mount. "Instant" results are then obtained by viewing a video monitor and watching the positional indicators. Quick look results and a preliminary indicator of the seeker status are available five minutes following a test flight to assist in planning future flights. Seeker signals and video with positional indicators are recorded on magnetic tape for further in-depth analysis and for use in computer simulations.



PYROELECTRIC DETECTORS

Pyroelectric detectors are in use for making radiant intensity measurements of emissive sources in both field and laboratory testing. The pyroelectric systems consist of a Laser Precision Model kT-3000 $LiTaO_3$ detector, a preamplifier and chopper. The detectors are spectrally flat in the region from 0.2 - 20 micrometers and are equipped with bandpass filters to select the appropriate band of interest. The systems are typically used at ranges of 10 - 30 meters with no collecting optics. The field of view of the systems at the 50 percent points is 12 degrees.

The output of the detectors is fed into lock-in amplifier. The output of the amplifier is recorded by any number of methods including direct analog to digital conversion by personal computers or recording on a digital storage oscilloscope.



PYROELECTRIC DETECTORS AND DETECTION SYSTEMS

kT-3000 SERIES: MODULAR HIGH PERFORMANCE DETECTORS, PREAMPLIFIERS, AND ACCESSORIES

The new kT-3000 series capitalizes on Laser Precision's many years of experience pioneering the use of double oxide crystals for sophisticated pyroelectric applications ranging from laboratory instrumentation to deep space. It is the successor to the popular kT-1000, 2000 and 4000 series, combining the compact TO-5 detector mounting of the kT-2000 with a low-microphonic design guaranteeing a minimum sensitivity to vibration and air coupled acoustic effects.

Three detector element designs are available: 1) kT-3100 for economy and broad response, 2) kT-3300 for high speed applications, 3) kT-3500 for the ultimate in spectral flatness.

These elements can be wired directly into the user's circuitry or can be plugged into one of the kTH series preamplifiers. In the latter case, the system frequency response will be determined by selection of the appropriate response module. A variety of accessories provides for system flexibility and performance optimization.

kT-2200 SERIES: INTEGRAL DETECTOR/PREAMPLIFIERS

kT-2200 series detectors consist of pyroelectric elements of the kT-3100 type combined with integral J-FET voltage mode preamplifiers. They are intended for use in applications such as gas analysis and intrusion detection requiring overall detector/preamplifier compactness and low cost. The use of lithium tantalate elements results in excellent stability, sensitivity and reliability and the low-microphonic structure facilitates consistent performance under a wide variety of environmental conditions.

kT-1500 SERIES: SUBNANOSECOND PULSE DETECTORS

kT-1500 series pyroelectric detectors are designed specifically for use in the study of intense infrared pulses such as those obtained from TEA CO_2 lasers. Response times of less than 100 picoseconds have been reported, with output levels of typically 100 millivolts. This rapid response is made possible by the use of a 50 ohm coaxial structure designed for impedance matched UHF operation. Under most conditions, these detectors can be fed directly into a fast oscilloscope without preamplification. Although they are normally supplied with a protective Irtran II window, this can be easily removed and the window holder interchanged with the kTC-102 light condensing cone or the kTF-110 lens assembly.

LARGE AREA AND CAVITY DETECTORS

In addition to the general purpose detectors described in this data sheet, a number of specialized pyroelectric detectors are available. These include the RkP-300 series energy monitors, low cost detectors with areas to 4cm², and the RjP-700 series energy probes. The latter group includes the 735 cavity detector which serves as a standard of spectral flatness in the visible and infrared regions.

kT-3000 Features

- $LiTaO_3$ elements for high stability
- Reduced microphonic TO-5 structure
- Modular preamplifiers for performance optimization
- Plug-in frequency response modules
- Choice of three coatings:
  1. Gold black for ultraflat spectral response
  2. Metallic for high speed
  3. Organic black for economy and broad response
- Available accessories include choppers, modular optics and electronics.

kT-2200 Features

- Low output impedance
- 1/f Frequency response between 2 Hz and 2 kHz

kT-1500 Features

- Subnanosecond pulse resolution
- Alternate energy integration mode
- No preamplifier or power supply required
- Near to far IR response (regular model)
- UV to far IR response (Option S model)

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SYSTEM SELECTION

SPECIFICATION OF A DETECTION SYSTEM starts with the selection of the detector/preamplifier/load module combination best suited to give the desired sensitivity, bandwidth, and dynamic range. Optical and electronic accessories can then be included as required, or added later.

DETECTOR ELEMENTS

The three standard kT-3000 Series Detectors are determined by their coating type.

STANDARD MODELS (kT-3000 Series)		kT-3100			kT-3300			kT-3500		
		kT3110	kT3120	kT-3130	kt-3310	kT-3320	kT-3330	kT-3510	kT-3520	kT-3530
Element Diameter (mm)		1.0	2.0	3.0	1.0	2.0	3.0	1.0	2.0	3.0
Current Responsivity, (μA/W)*	typ.	1.5	1.6	1.3	1.2	1.2	1.1	1.8	2.0	1.6
	min.	1.0	1.0	1.0	0.8	0.8	0.8	1.3	1.4	1.2
Capacitance, nom. (pF) C_d		15	60	113	15	60	113	17	67	125
Dissipation Factor, nom. (decimal)		.005	.004	.003	.006	.006	.004	.006	.006	.005
$\sqrt{C_d D}/r_i$	max.	0.18	0.31	0.45	0.25	0.50	0.61	0.18	0.32	0.49
Thermal Time Constant (ms)	min.	100	100	100	100	100	100	100	100	100
Crystal Thickness (microns)	typ.	25	25	30	25	25	30	25	25	30
	max.	35	35	40	35	35	40	35	35	40
Aperture Diameter (mm)		2.0	3.0	4.0	2.0	3.0	4.0	2.0	3.0	4.0
Max. Recommended Aver. Power (mW)		80	200	300	80	200	300	40	100	150
Max. Peak Power Density (MW)		NA	NA	NA	1	1	1	NA	NA	NA

*No window value. To determine value with window multiply window transmission.

SERIES	*COATING TYPE*	MAX. POWER DENSITY W/cm²	SPECTRAL RESPONSE	COATING ROLLOFF FREQ., kHz, min.	RISE *TIME*, μ sec.
kT-3100	Black paint on gold electrode	10	0.25μ to 20μ†	2	175
kT-3300	*Semitransparent metallic electrode*	10	<0.2μ to >400μ	800	.44
kT-3500	Gold black, metallic electrode	5	<0.1μ to >400μ	7	50

†Customer feedback indicates responsivities in 0.1μ to several Å region identical to visible responsivities.

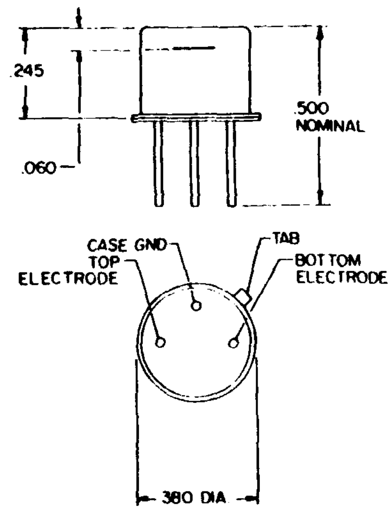
STANDARD WINDOW MATERIAL

Irtran II (suffix I) or Suprasil (suffix Q). For example a 1mm detector of kT-3100 type with a Suprasil window would be kT-3110 Q. A no window version (suffix N) may be ordered but without the reduced microphonics of the windowed models. There is no price difference among the I, Q, or N options. See page 3 for window transmission curves.

LOAD MODULES

The gain and bandwidth characteristics of a kT-3000/preamplifier system are determined by plug-in modules as well as the inherent frequency limit of the particular preamplifier selected. One resistance module of customer specified resistance is supplied with each preamplifier. Other resistance modules are available. Standard resistance modules have the designation kTZ-9ex where ex is the exponent (base 10) of the resistance value. Nominal resistive values range from 10^3 to 10^{12} ohms (kTZ-903 through kTZ-912).

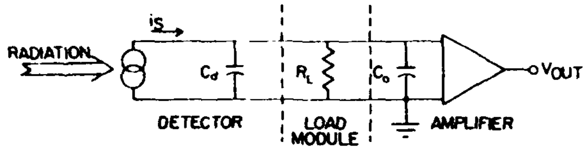
kTZ-800 series capacitive modules are used to provide accurate integrating capacitances for measuring total pulse energy. They also can be used to limit system responsivity without introducing Johnson noise. They are designated kTZ-8NM where the capacitance is N x 10^M pF.



AMPLIFIERS

kTH-100 Series Preamplifiers are FET input current mode devices designed to provide optimum performance at the extremely high impedances characteristic of pyroelectric detectors. For maximum signal-to-noise ratio they should be operated with high value feedback resistors (load module kTZ-911 or 912). Lower value resistors yield greater bandwidth.

kTH-100 amplifiers can be operated effectively at bandwidths up to about 500 kHz. For greater bandwidths Model kTH-313 voltage mode amplifier is recommended. The kTH-313 is a FET input voltage mode device having a low output impedance, output signal levels of greater than one volt, and a voltage noise level of less than 10 nanovolts/$Hz^{1/2}$ above 100kHz.



KT-3000/333 EQUIVALENT CIRCUIT

OPTICAL, MECHANICAL AND ELECTRICAL ACCESSORIES

The following collecting optics mount directly on the preamplifier load module or kT-1500 detector housing in place of the standard window housing.

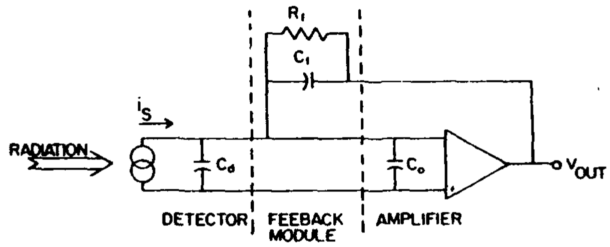
kTF-110 Lens Assembly: An F:1 optical system with a range of adjustment allowing source to lens distances from six inches to infinity. The standard lens is uncoated Irtran II. Other lenses are available.

kTC-102 Light Condensing Cone: A 10° included angle polished brass cone with entrance and exit diameter of 20mm and 2mm respectively.

kTA-140 Adjustable Rod and Stand: A 1½ lb. rectangular stand with a thumb screw set rod allowing vertical adjustment of detector assembly from 5½" to 8½" above support plane. Threaded rod mates with preamplifier load modules or kT-1500 detector housing.

CTX-534 Variable Speed Chopper: A phase-locked speed controlled optical chopper with frequency range from 5 to 4000 Hz and an auxiliary sync output. For detailed specifications see data sheet PS-534-04.

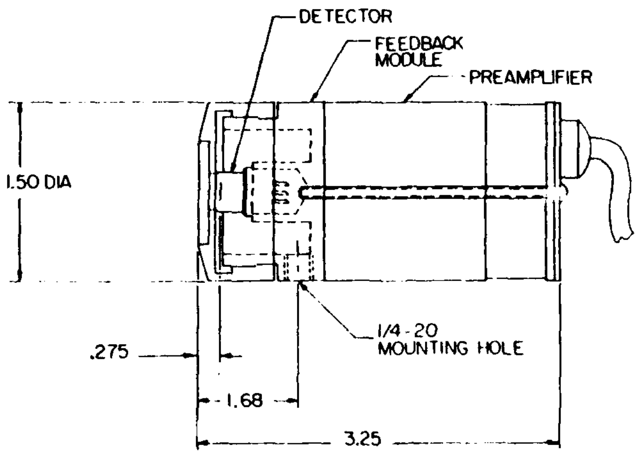
kTS-215 Power Supply: A ±15V, 25mA regulated power supply to operate kTH-333 or kTH-100 preamplifiers. The preamplifier cable mates directly to the power supply. A BNC connector on the power supply chassis provides the kTH-100 preamplifier output.

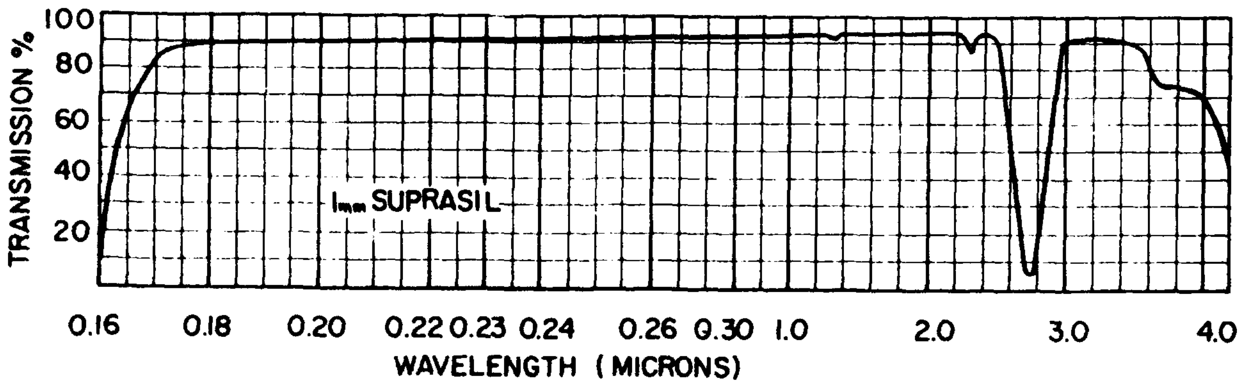


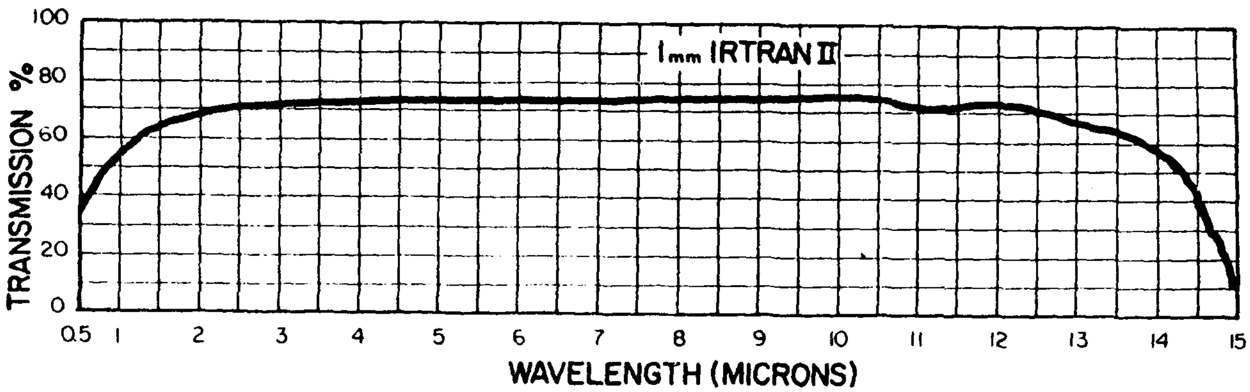
KT-3000/100 EQUIVALENT CIRCUIT

AMPLIFIER SPECIFICATIONS

	Current Mode kTH-103	kTH-113	kTH-193	Voltage Mode kTH-313
i_{nA}(Amps/$Hz^{1/2}$)	1.6×10^{-15}	0.7×10^{-15}	1.6×10^{-15}	0.7×10^{-15}
v_n(nV/$Hz^{1/2}$), 20Hz	150	75	25	150
v_n(nV/$Hz^{1/2}$), 100Hz	100	50	15	100
v_n(nV/$Hz^{1/2}$), 1kHz	50	25	3	40
v_n(nV/$Hz^{1/2}$), 10kHz	30	15	2	15
v_n(nV/$Hz^{1/2}$), 50kHz	30	10	1.5	12
Effective Input Cap. (pF)	25	25	100	1
Output Impedance (ohms)	50	50	50	100
Operating Voltage	±15Vdc	±15Vdc	±15Vdc	+12 to 15Vdc
Current Drain max.	6ma	6ma	6ma	6ma







SYSTEM OPERATION

A pyroelectric detector is a capacitor formed by depositing metal electrodes on a thin slice of ferroelectric material. As a capacitor it should be thought of as strictly an A.C. device. The detector response results from the dependence of polarization on temperature. A change in detector polarization will give rise to a displacement current in the detector material and a compensating current flow in the external measuring circuit equal to

$$i = \int_A \left(\frac{dP}{dt}\right) dA \tag{1}$$

where A is the electrode area, P is polarization and t is time. For uniform heating

$$i = (\Lambda)\frac{dT}{dt}(A) \tag{2}$$

where the pyroelectric coefficient, Λ, is the rate of change of polarization with temperature i.e. $\frac{dP}{dT}$, and $\frac{dT}{dt}$ is the time rate of change of detector element temperature caused by the absorption of the incident radiation.

For the idealized case of no heat loss and uniformly absorbed radiation the detector temperature will increase linearly with constant input flux and

$$\frac{dT}{dt} = \frac{\epsilon W}{C_p \rho A d} \tag{3}$$

so that

$$i = r_i W \text{ where } r_i = \frac{\epsilon \Lambda}{C_p d \rho}. \tag{4}$$

Here ϵ is the absorptance of the detector, W is the total incident power, ρ is the detector material density, C_p is its specific heat, d is the electrode separation and r_i is called the current responsivity.

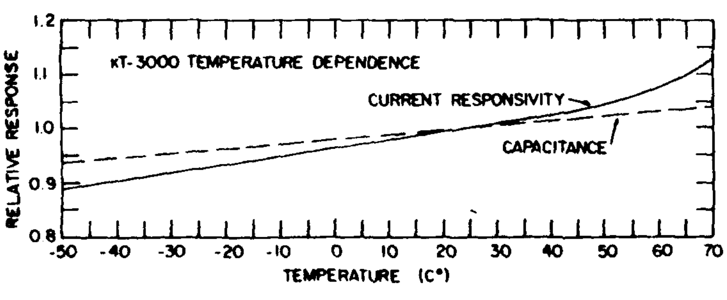
For a real detector heat loss to its surroundings causes the detector element temperature to approach a constant value, at which the rate of heat loss is equal to the rate of heat input from the radiation flux. The decrease in dT/dt results in the characteristic "droop" of the output current. The response time of any coating used to enhance the absorptance gives rise to the rounding of the current pulse's leading edge (where dT/dt = maximum).

The inherent speed of a pyroelectric detector is due to the fact that it responds to the rate of change of temperature, rather than directly to the temperature itself.

The basic equivalent circuit of a pyroelectric detector is simply a current source in parallel with its own capacitance. To convert the low level current output obtained to a voltage at a convenient impedance level, it is necessary to use a high impedance current-to-voltage converting preamplifier. The equivalent circuits for two common amplifier types, a current mode operational amplifier and a voltage mode FET follower, are shown on page 3

For a further discussion of pyroelectric detectors, see:

W. M. Doyle: EOSD, December Issue, 1978 A User's Guide to Pyroelectric Detection.



PERFORMANCE EVALUATION

Assuming that the modulated incident radiation can be analyzed into its sine wave components, the current responsivity will be given by

$$r'_i(f) = r_i K_L(f) K_H(f) \tag{5}$$

where r_i is the frequency independent responsivity, f is the modulation frequency and $K_L(f)$ and $K_H(f)$ are factors representing the low frequency and high frequency roll-offs respectively.

For a uniformly heated detector element and a simple thermal circuit involving only the heat capacity of the detector element and a fixed thermal conductance path to a good heat sink, the droop characteristic will be an exponential decay and K_L will have the form:

$$K_L = 1/[1 + 1/(2\pi f T_d)^2]^{1/2} \tag{6}$$

where T_d is the thermal time constant or droop time. This represents a low frequency roll-off of 6db per octave.

The effect of an absorbing coating is somewhat more complicated, but can be approximated by the expression:

$$K_H = 1/(1 + f/f_b)^{1/2} \tag{7}$$

where f_b is the roll-off frequency of the coating. The coating thus produces an approximately 3db/octave effect.

The voltage responsivity of the detector/preamplifier combination is:

$$r_v = r'_i ZG \text{ (Volts/Watt)} \tag{8}$$

where Z is the impedance of the feedback circuit or of the input circuit for the current or voltage preamps, respectively. Z can be written:

$$Z = R/(1 + f^2/f_c^2)^{1/2} \tag{9}$$

where $f_c = 1/2\pi RC$. R and C are the feedback resistance and feedback capacitance (typically .3 pF) for current mode preamplifiers or the load resistance and the sum of the detector and amplifier input capacitance, $C = C_o + C_d$, for voltage mode preamplifiers. The gain factor, G, is equal to one for a current mode amplifier and typically 0.7 for a FET follower.

In order to determine the signal-to-noise ratio to be anticipated in a given application, it is necessary to evaluate all possible noise sources. Four significant sources of electrical noise are: Johnson noise due to the feedback resistance (i_{nJ}), amplifier current noise (i_{nA}), amplifier voltage noise (i_{nV}), and dielectric loss noise (i_{nD}).

The total electrical noise is obtained by adding the various noise currents in the rms sense:

$$i_{nT} = (i_{nJ}^2 + i_{nA}^2 + i_{nV}^2 + i_{nD}^2)^{1/2} \text{(amps/Hz}^{1/2}\text{)}. \tag{10}$$

The individual noise contributions can be evaluated by using the following expressions:

$$i_{nJ}^2 = 1.69 \times 10^{10}/R_f \tag{11}$$

$$i_{nV}^2 = 3.95 \times 10^{-11} f^2 (C_o + C_d)^2 v_n^2 \tag{12}$$

and

$$i_{nD}^2 = 0.106 f C_d D \tag{13}$$

where the noise currents will be in femtoamps (10^{-15} amps) if the units below are used:

R_f = feedback resistance (Ohms)
f = frequency (Hz)
C_d = detector capacitance (pF)
v_n = amplifier noise voltage (nV/Hz$^{1/2}$)
D = Dissipation factor (decimal)

The narrow band noise equivalent power, NEP, is given by the expression:

$$\text{NEP (narrow)} = i_{nT}/r'_i \text{ (nW/Hz}^{1/2}\text{)} \tag{14}$$

where r'_i is in μA/W.

The NEP term due to dielectric dissipation is proportional to $\frac{\sqrt{CD}}{r_i}$;

Maximum values for this factor are listed in the detector specification tables.

Evaluation of the broad band NEP is complicated by the different frequency response characteristics of the various noise sources. However, an approximate expression can be given if K_H and K_L are near unity in the band of interest, and if we assume a post amplifier providing a total response fall-off of 12db per octave at high frequencies. In this case:

$$\text{NEP (broad)} = \text{NEP (narrow)}\, K_N (f_{max} - f_{min})^{1/2} \text{ (nW)} \tag{15}$$

where K_N = 1.26 if i_{nA} or i_{nJ} is dominant,
= 1.73 if i_{nV} is dominant,
= 1.50 if i_{nD} is dominant,

and NEP (narrow) is calculated at f_{max}: These values were calculated under the assumption that two 6db/octave breaks are placed at 1.56 f_{max}.

In using the above expressions, it should be borne in mind that the noise currents given, and hence the NEP, are rms values. To evaluate signal to noise performance, these should be compared to rms signal levels. In the case of square wave optical chopping and narrow band electronic filtering, the rms value of the signal at the fundamental frequency is equal to 0.45 times the peak-peak signal.

The noise sources discussed above are characteristic of the detectors and amplifiers themselves. In addition to these

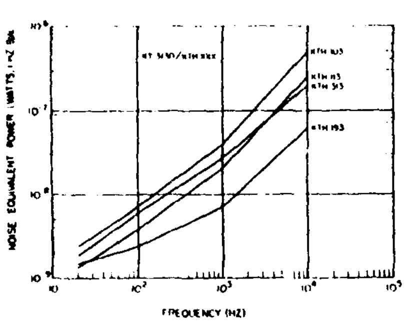
are sources relating to the experimental environment. These include electrical disturbances, vibration, and air-coupled acoustic effects. The kT-3000 series detectors are designed to minimize vibration and air-coupled microphonic effects. The vibration microphonic current obtained from a typical pyroelectric is given approximately by:

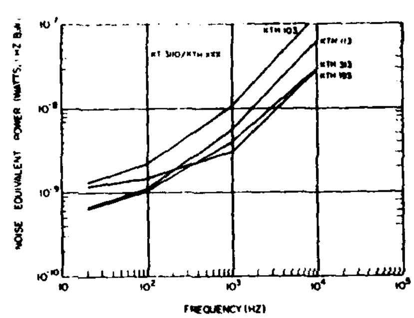
$$i_\mu = R_\mu AGfd \qquad (16)$$

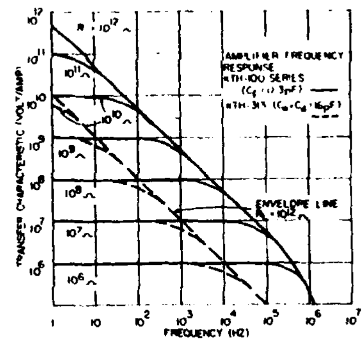
where A is the detector area in mm², G is the acceleration level in g's, f is the frequency, d is the crystal thickness in microns, and R_μ is a coefficient that depends on detector material and design. The typical value for R_μ for kT-3000 series detectors is

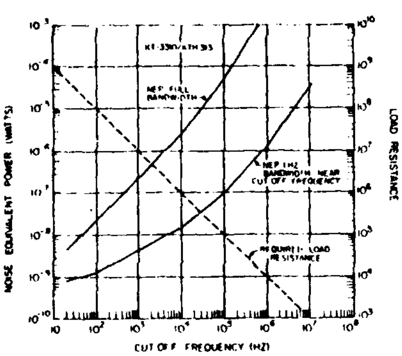
$$5 \times 10^{-17} \ \frac{\text{Amp (rms)}}{(\text{mm}^2)(\text{g})(\text{Hz})(\text{micron})}.$$

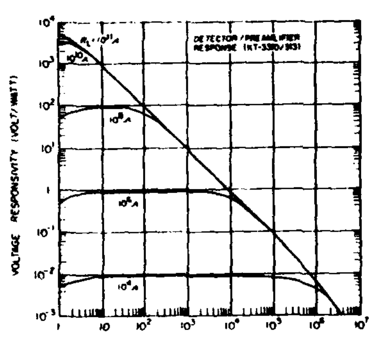
Thus the current of a kT-3110 at 100 Hz due to a 1g acceleration is about 9.8×10^{-14} Amp (rms).

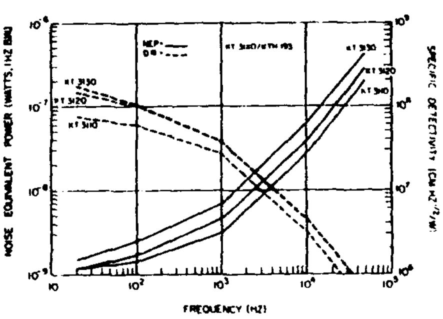


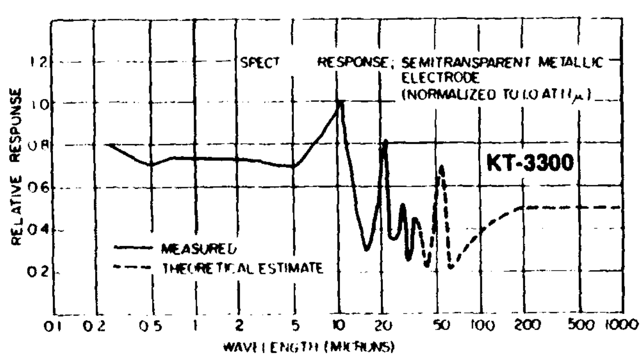


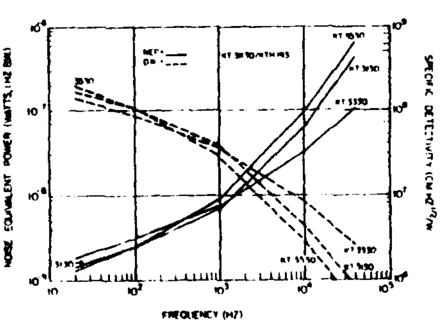


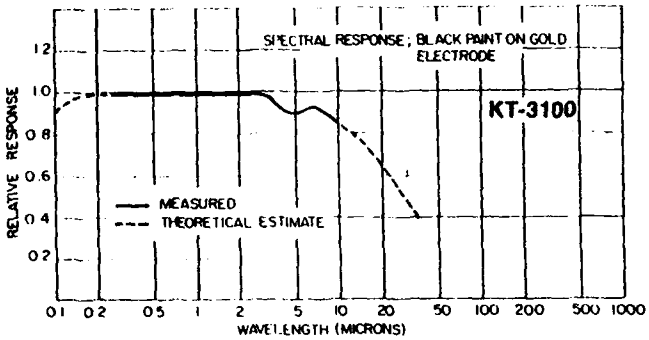


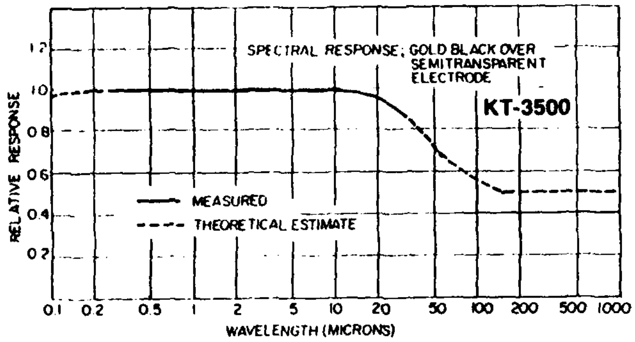


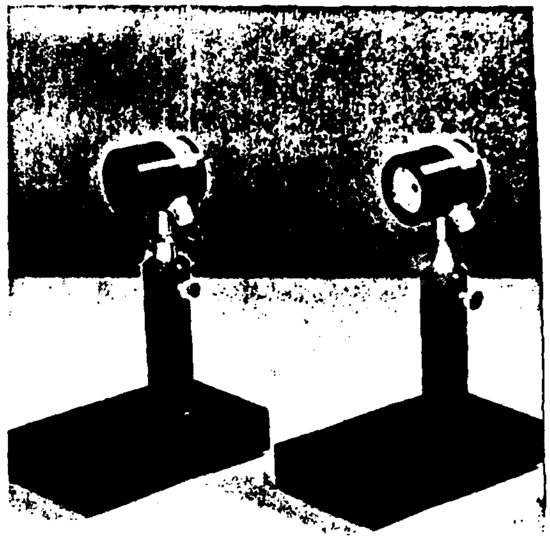












RkP-310 Group

LARGE AREA AND CAVITY DETECTORS PERFORMANCE SUMMARY

A total of five pyroelectric energy probes are now available from Laser Precision. These can be used with either an oscilloscope to serve as simple energy monitors or with an Rj-7000 Series Energy Readout for rapid and accurate pulse measurement. The table below summarizes the characteristics of the various probe models. Information concerning the readouts can be found in data sheet PS-70-01.

RkP-310 Group: Low Cost Probes

Models RkP-312 and 314 are intended primarily for use in conjunction with a conventional oscilloscope or other signal processing system having an input impedance of at least one megohm. They function to produce a voltage step function proportional to the energy of an input radiation pulse having any length less than about one millisecond. Since they do not use internal preamplifiers, no external power source is needed.

RkP-730 Group: High Performance Probes

Models RjP-734 through 736 have been designed specifically for use with the Rj-7100 single channel and 7200 dual channel readouts to provide sensitive and accurate measurement of pulses having lengths up to one millisecond and repetition rates to 30pps. They can also be used with an oscilloscope as long as the appropriate power is provided for their internal preamplifiers. Models RjP-734 and 735 feature a light trapping cavity detector structure which provides the ultimate in spectral flatness.

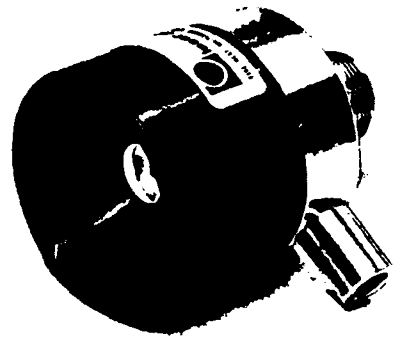
PROBE MODEL	RkP-312	RkP-314	RjP-734	RjP-735	RjP-736
Aperture: Diameter (cm)	0.5	2.25	2.54	1.13	5.05
Area (cm^2)	0.2	4.0	5.0	1.0	20.0
Equivalent Noise Level (Joules)	5×10^{-5}	1×10^{-4}	1×10^{-4}	1×10^{-7}	5×10^{-4}
Responsivity (Volts/Joules)	100	5.0	2.5 to 2.5×10^4	2.5 to 2.5×10^4	0.25 to 2.5×10^3
Maximum Energy (Joules)	0.1	2.0	2.0	1.0	10
Maximum Irradiance (W/cm^2, peak)	5×10^5	5×10^5	10^6	10^6	5×10^5
Detector Configuration*	Flat	Flat	Cavity	Cavity	Flat
Minimum Matching Impedance (ohms)	10^6	10^6	N/A	N/A	N/A
Required Voltage (Volts)	None	None	±15	±15	±15
Dimensions: Diameter (inches)	1.5	1.5	2.0	1.5	3.0
Length (inches)	1.6	1.6	8.0	7.0	8.5

*Spectral Response: (1) Cavity Detector: ±½% (0.4–3μm); +½%, −4% (0.25–16μm)
(2) Flat Detector: ±3% (0.4–1μm); +3%, −9% (0.35–11μm)

PYROELECTRIC PULSE DETECTORS

kT-1500 SERIES		kT-1510	kT-1520	kT-1540
Element Diameter (mm.)		1.0	2.0	4.0
Current Responsivity,	Regular	.08	.04	.02
(A/MW at 10.6μ)	Opt. S	.30	.15	.15
Capacitance (pF, max.)	Regular Option S	5 10	5 10	5 10
Spectral Response	Regular Option S		7μ to Far IR UV to Far IR	

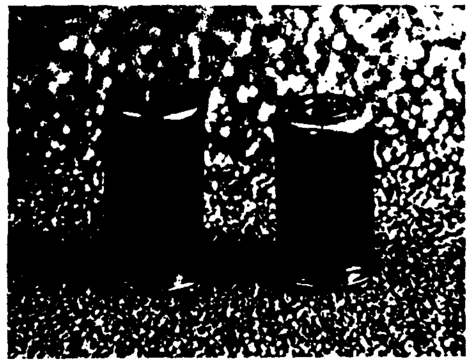
Response Time, max. .... <1 nanosecond
Maximum Peak Power Density 1MW/cm²
Operating Temperature .... −30°C to 75°C
Window .... Removable Irtran II
Dimensions .... 1.5" dia. x 2.25" length
Power Requirement .... None
Output Connection .... Type N connector, in to 50 ohms



kT-1500

HYBRID DETECTORS/PREAMP

kT-2200 SERIES	kT-2210	kT-2220	kT-2230
Element Diameter (mm)	1.0	2.0	3.0
Voltage Responsivity (20 Hz) min. v/w	300	100	50
NEP (20 HZ, 1 Hz), max. W/Hz$^{1/2}$	1.4x10^{-9}	2.1x10^{-9}	3.0x10^{-9}



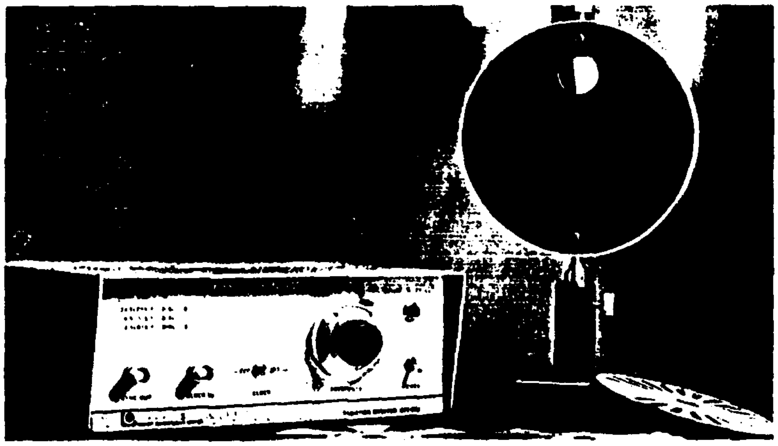
kT-2200

Spectral Response (detector element) .... 0.4μ to 40μ (i.e. kT-3100)
Frequency Response (detector element) .. 2Hz to 2kHz
Maximum Recommended Power Density .. 10W/cm²
Operating Temperature .... −30° to 75°C
Window* .... Irtran II
Suprasil
No Window
Dimensions .... TO-5 can type
.327±.002" dia.
.630±.010" length
Power Requirement 6–20Vdc
Input, Output Connection .... 3 pins, 0.2" B.C.

*Window affects detector spectral response. See transmission curves. Use same window identification suffixes as for kT-3000 Series. Quoted NEP for windowed detectors only.

kT-3000

CTX-534 VARIABLE SPEED OPTICAL CHOPPER



DESCRIPTION:

The CTX-534 is a compact high performance radiation chopping system designed for convenient optical bench mounting. It consists of a light weight, 4½ inch diameter chopper blade driven by an efficient DC motor and a separate phase-locked speed controller. A particularly convenient feature of the mechanical assembly is a unique guard design which allows the one inch clear aperture to be freely moved to any position around the chopper circumference. This provision is ideal for compact bench top arrangements. Three blade designs are available to cover the rated frequency range.

The high-gain speed controller is supplied with a four foot cable for connection to the chopper assembly. The sync signal is obtained from an optoelectronic pickoff in the chopper, and an auxiliary output pulse is provided at the chopping frequency for synchronization of subsequent electronics. The motor speed can be set by means of a precision ten turn potentiometer. In addition, provision is made for synchronization to an external clock. *Motor speed varies from 150 to 10,000 RPM.*

SPECIFICATIONS

Frequency Range	5 to 4000 Hertz
Long Term Stability	0.1%
Phase Jitter (Radians)	0.05N at min. speed; 0.01N above ¼ max. speed (N = number of slots)
Temperature Coefficient	.1% per degree C.
Sync Output	5 Volt TTL Compatible
Sync Input	3 to 5 Volts, 60 to 4000 Hertz, square wave
Required Power	115 volts, 30 watts
Mounting	¼-20 hole; Supplied with ½" diam. rod and stand

CHROME BLADE: 503, 504, 505; BLACK: 513, 514, 515

Designation	Number of Slots	Aperture Width	Freq. Range
CTD-503/513	2	1.0"	5-333Hz
CTD-504/514	6	0.9"	15-1000Hz
CTD-505/515	24	0.23"	60-4000Hz
CTD-500	Blank		
CTD-525	Calibrated 2% Duty Cycle Blade		

CTX-534 FEATURES

- —Optical Bench Mounting
- —Movable Aperture Position via Thumb Screw
- —Rapid Blade Interchange
- —Phase-Locked Speed Control
- —Auxiliary Sync Output
- —Aperture heights 6" min to 12¼" max above Table with stand

Also available
Fixed Speed Choppers

CTX-515	15 Hz
-530	30 Hz
-532	32 Hz

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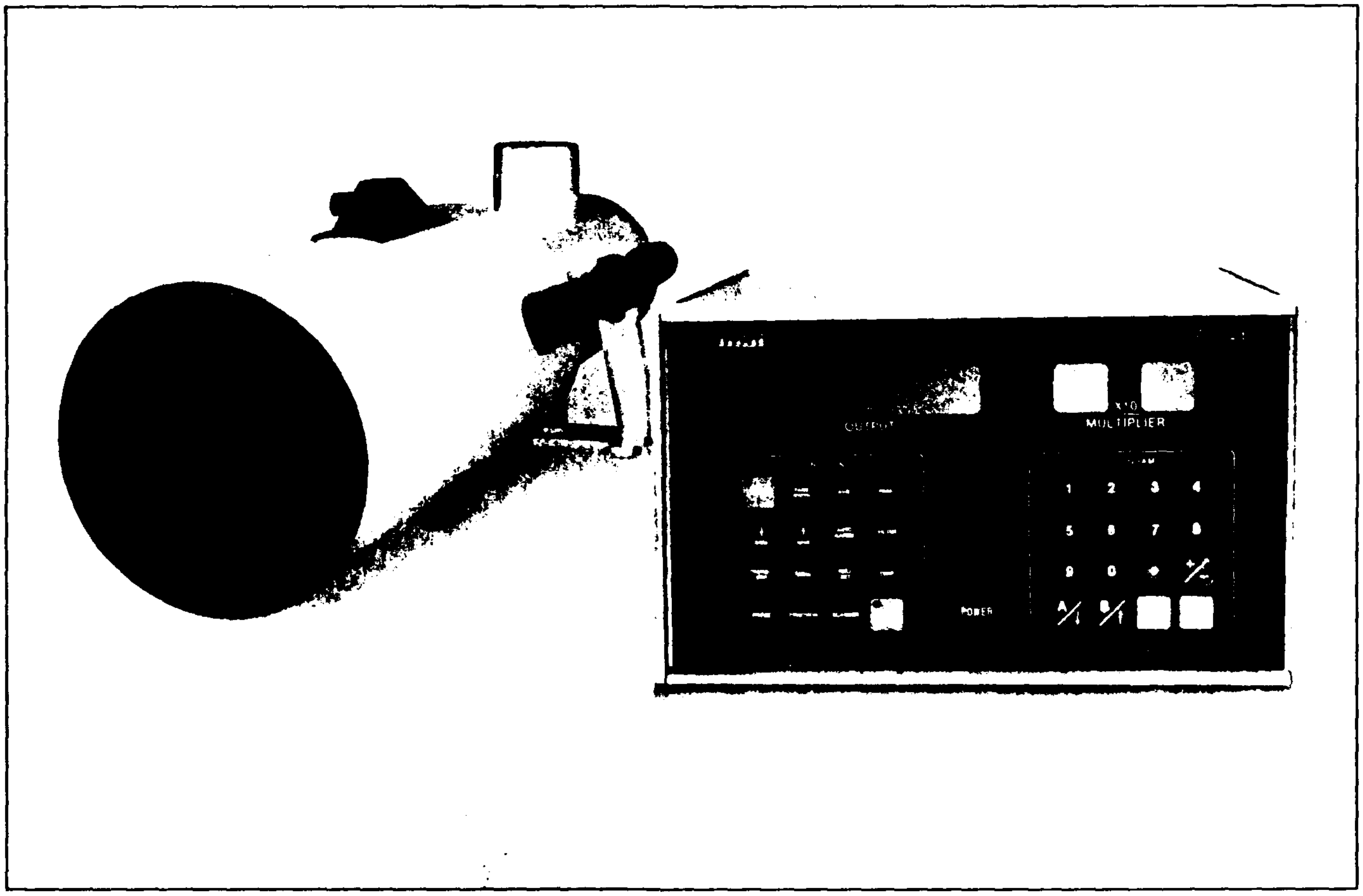
INFRARED BANDED RADIOMETERS

The Minirad Model SA-100 and SA-1000 are banded radiometers used for field measurements of emissive sources. The SA-100 system consists of an optical head and controller. The SA-1000 system has the optical head, the controller and a dedicated data acquisition/data analysis system. The optical heads contain a liquid nitrogen cooled InSb detector and are useful in the 1.1 - 5.5 micrometer wavelength. Both systems are equipped with refractive collecting optics and are used at ranges from 0.1 - 5 km. The field of view of the SA-100 instrument is 3.8 degrees at the 80 percent power points. The field of view of the SA-1000 is either 4.5 or 20 degrees depending of the choice of fore optics. The detector is chopped at 1000 Hz. A manual filter wheel with up to 10 bandpass filters is used to select the wavelength region of interest.

MINARAD SYSTEMS INC.

INFRARED SPECTRAL ANALYZER MODEL SA-100, MODEL SA-200



The Model SA-100 and SA-200 Infrared Spectral Analyzers are designed to measure radiation in the 0.5 and 20.0 micron spectral region. They are micro-processor controlled and capable of accepting cooled detectors and circular variable filter wheels. The capabilities and design philosophy of these instruments make them especially suitable for dedicated applications such as: calibration radiometers for use as transfer standards; remote sensing instruments for background and target measurements; energy measurement for research and military applications; flare measurements, and; material studies.

These systems have been designed to meet those applications demanding highly sensitive, stable instruments capable of producing accurate data. In addition, the system is lightweight for one-man operation and portable for simple installation in the field or in a vehicle or aircraft.

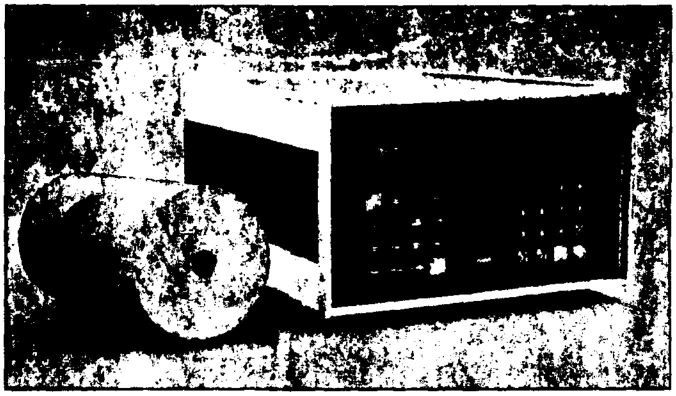
Interchangeability in the electronic architecture and modularity in the optical system allow expansion of the system while retaining the initial cost-effective price. The SA family of instruments has been designed to interface directly with computers and automatic test equipment supplied by the customer.

SYSTEM CONFIGURATION

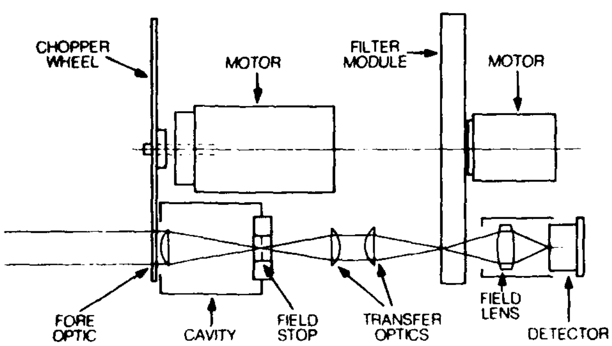
The difference between the Model SA-100 and the Model SA-200 is that the Model SA-100 utilizes refractive optics and is designed primarily for wide fields-of-view, from 1 to 6 degrees; the Model SA-200 utilizes reflective optics and is designed primarily for field-of-view of 2 degrees and smaller.

The instruments consist of two parts: an optical head and an electronic processing console.

OPTICAL SYSTEM OF MODEL SA-100



The Model SA-100 optical head has a refractive collecting optical system which focuses the infrared energy onto the system field stop. The mechanical modulator is placed in front of the collecting optics to modulate the incoming radiation and compare it with a temperature-controlled reference cavity. Two transfer lenses focus the energy onto the plane of the filter system, and a third lens transfers the image of the field stop onto an interchangeable detector package.



SA-100 OPTICAL LAYOUT

The Model SA-100 incorporates an external boresight telescope and an optional viewer can be inserted into the system in front of the modulator to help align the head with the target.

The instrument incorporate special optics for:

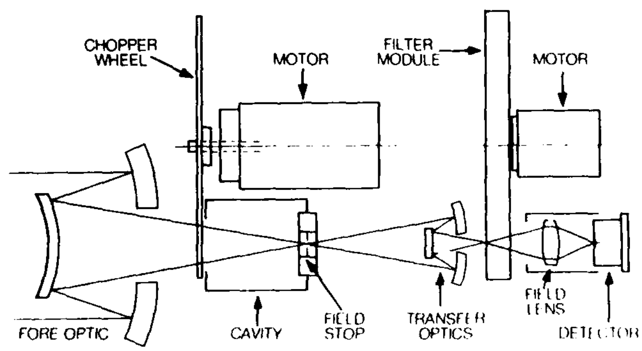
- Small spot size targets at close working distances
- Targets in obscured locations
- Solar applications
- Extreme wide angle applications

OPTICAL SYSTEM OF MODEL SA-200

The optical system of the Model SA-200 is designed in modular form. The standard instrument is designed with a 6.0" high resolution Cassegrain fore-optic assembly.

The modular transfer optics of the system are fully reflective, thereby assuring virtually constant energy transfer over a very wide spectral region, from the visible to beyond 30 microns. The packaging of the system has been designed to assure alignment between the mechanical and the optical axis. This is accomplished by using adjustments for both the primary and secondary mirrors.

Energy from a target is collected by the fore-optics and is focused onto the system field stop, which is enclosed in a heated reference cavity. A rotating chopper is placed before the field stop assembly and modulates the incoming beam. The energy, after passing through the field stop, is imaged by the transfer mirrors onto the plane of the filter wheel module. This system is designed so that both the field stop and the filtering system are in focus for maximum resolution. The energy is then imaged by the field lens onto the detector. The field lens is designed to focus the system pupil onto the detector to insure constant spatial illumination of the detector.



SA-200 OPTICAL LAYOUT

The Model SA-200 incorporates on-line sighting to enable clear imaging of the target during alignment. The signal can be peaked during alignment and calibration with this sight since it intercepts only 50% of the incoming energy. A special sighting arrangement can incorporate a special wide-angled feature which permits target observation or photography during operation.

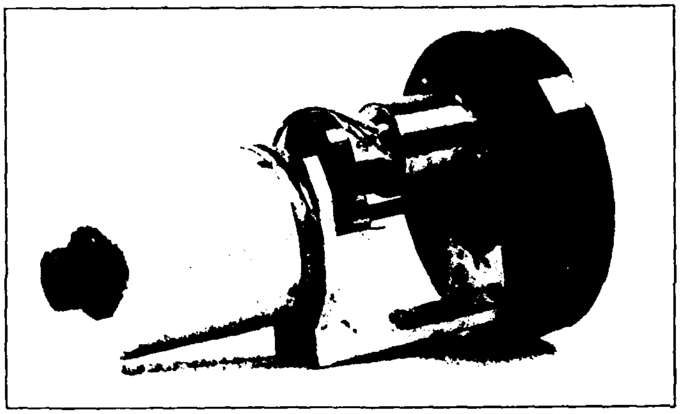
An external boresight telescope is supplied with every instrument.

FILTERS

The filter assembly consists of a ten-position filter wheel or a circular variable filter wheel. Either may be manually operated or motor driven. A full spectrum of filters is available for different applications, from visible to 20 microns.

The spectrum from .4 to 2.5 or from 1.3 to 14 microns can be covered on one Continuous Variable Filter Wheel.

All filter modules are self-contained and interchangeable in the field. Motor driven filter packages contain their own motor and absolute encoder.



DETECTORS

The detector packages consist of a prealigned detector field lens and entire analog processing channel. The solid-state detectors operate in temperature-controlled or cooled environments. See Figure 1 for typical field-of-view and performance of different detectors.

All detector packages are interchangeable, can be replaced in the field, and do not require factory recalibration or realignment.

FIGURE 1. A selection of detectors is available to enable the user to optimize the system bandwidth, depending upon the analysis requirement.

Detector	Wavelength	SA-100 NEPD 10 Hz, 6.0° FOV	SA-200 NEPD 1 Hz, 3 mr FOV
Pyroelectric	2.0–20.0	7.5 x 10E-8	1 x 10E-10
Silicon	0.5–1.0	1 x 10E-10	1 x 10E-13
Lead Sulphide	0.7–2.5	1.7 x 10E-10	1 x 10E-13
Lead Selenide	1.0–5.0	1.7 x 10E-8	2 x 10E-12
Indium Antimonide	1.1–5.5	1.0 x 10E-10	8 x 10E-14
Mercury Cadmium Telluride (−30°C)	3.0–5.0	1.4 x 10E-9	1.4 x 10E-12
Mercury Cadmium Telluride (77°K)	2.0–14.0	1.0 x 10E-10	1.4 x 10E-12

ELECTRONIC PROCESSING

In all cases, the system uses a microprocessor-based system which gives full control and data signal conditioning for any specific task. The systems are designed in such a way that as the tasks become more complex, the necessary dedicated circuits and a second computer can be added to perform real time processing and control of the system. This distribution of intelligence allows the SA system to accomplish measurement tasks other computer controlled systems can not accomplish. Wherever necessary, a second computer is added to perform multiple tasks in real time where the use of serial processing or external computers is not feasible. This capability becomes a necessity for applications such as:

- –transmissometry
- –reflectometry
- –pyrotechnics

The system utilizes a standard bus construction for ease of maintenance and future expansion. RS-232 and IEEE interfaces are available for link-up to the customer's computer systems. The customer has the option of controlling the units from his centralized computer. In addition, the system can be supplied with an external computer, including software for specialized applications.

SPECIAL APPLICATIONS

Minarad Systems Inc. is an engineering company specializing in radiometry. We can assist you in solving your specific measurement problems.

In addition to the standard "SA" family of radiometers, we can also offer special instruments to solve your particular measurement problem.

SYSTEMS SPECIFICATIONS

Optical Field of View	
A. Model SA-100	
Standard	1.0 to 6.0° ±25% at 50% transmission point, measured at infinity focus
Optional	0.35°, 0.7° ±25% tolerance, measured at 50% power transmission point
B. Model SA-200	2.0° and smaller
Spectral Region (Standard Detector)	
A. Model SA-100 B. Model SA-200	Pyroelectric 1.8–20 microns
Optional for both models	All commercially available detectors covering the range from 0.5–16 microns or more.
Visual Sighting	
A. Model SA-100	*Bore sighted telescope* Optical viewer optional for narrow refractive field of view
B. Model SA-200	Bore sighted telescope See-through sight, non-parallax.
Reference	
Absolute internal reference, in-line	45°C with ±0.5° stability
Entrance Aperture	
A. Model SA-100	
Standard 5.0° FOV	1.0 cm diameter
Optional FOV's	3.5 cm diameter
B. Model SA-200	
Standard	6"
Optional	Other optics available on request.
Display	
Output	4½ digit display
Power of ten	2 digit display
Electronic radiance offset	Switched to output display
Filter position	Binary and analog voltage
Optical Modulating Frequency	
Standard Rate	100, 200, 400, 800, 1600 Hz

Signal Outputs	
Signal	Binary output
Analog output	−10V/0/+10VDC at 100 ohms
Filter position (optional)	0.1–10.0 volts DC at 100 ohms
Computer interface (optional)	RS-232, serial
Frequency Response, Output	
Standard	1, 10 100 Hz
Optional	Special frequency on request
Dynamic range	10^5
Signal Attenuation	
Standard	1 to 1000 in steps of 1, 2, 5, 10
Optional	Auto ranging (time constant 60 ms per step)
Offset Control (ERO)	Digitally variable from 1–1000
Filter Wheel Systems	
Manual discrete filters	2 x 10 position filter wheel
Manual CVF filter wheel	2.5–14 microns, with potentiometer output
Motor driven discrete filter wheel	2 x 10 filter positions
Motor driven CVF wheel	2.5–14 microns, with encoder output
Motor control system	
SA-100 standard:	45 sec./scan
SA-200 standard:	1 sec./scan (optional .5 sec./scan)
Mechanical Dimensions	
Optical head	
Model SA-100:	7.0" diameter x 17" long
Model SA-200:	7.0" diameter x 25" long
Electronics	11.5" high x 7.5" wide x 16" deep
Power requirement	115/230 volts ±10%, 60/50 Hz 250 watts maximum

MINARAD SYSTEMS INC.

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AUTOMATED INFRARED TEST FACILITY

The Automated Infrared Test Facility (AIRTF) is used for lot acceptance testing of infrared decoy flares. The facility was constructed inside a specially modified inert storage warehouse. The facility consists of a burning chamber, a tunnel and four support rooms adjacent to the tunnel. The burning chamber in the AIRTF is 16 meters long x 8 meters wide x 6 meters high. The tunnel in the AIRTF is 8 meters wide by 50 meters long. A 0.8 meter high baffle is installed on the floor of the tunnel at a distance of 15 meters from the center of the burning chamber to eliminate reflections from the floor. The restricted opening into the burning chamber provides a natural baffle on each side.

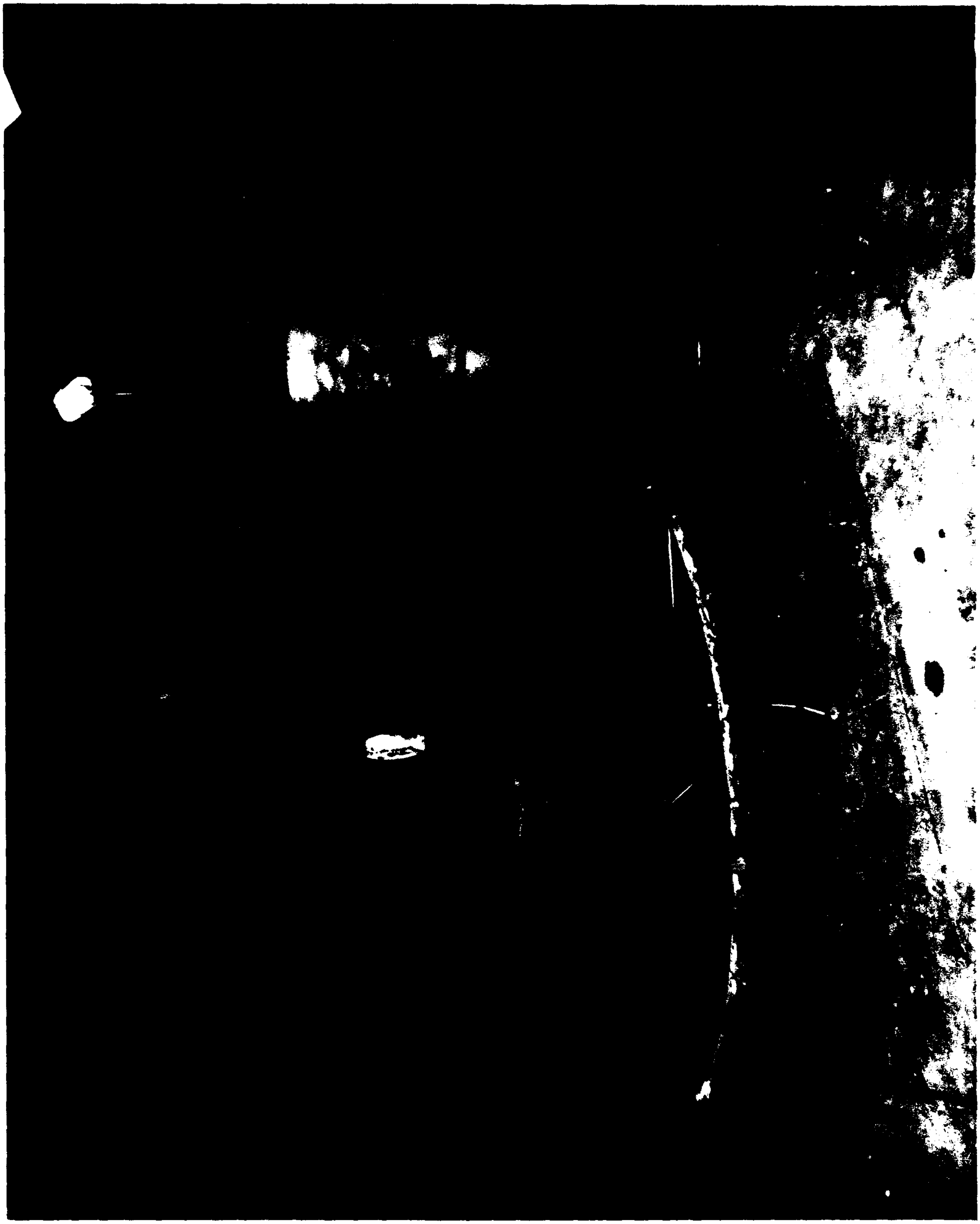
In the AIRTF air flow for removal of combustion products is from bottom to top. In a static burn the air speed around the flare is controlled by pushing air through the floor and exhausting combustion products from the top. In an air stream test the push air from the bottom is eliminated and replaced with the actual air stream simulator. The combustion products are exhausted through a bag house equipped with filters to remove any solid particulate before release to the atmosphere.

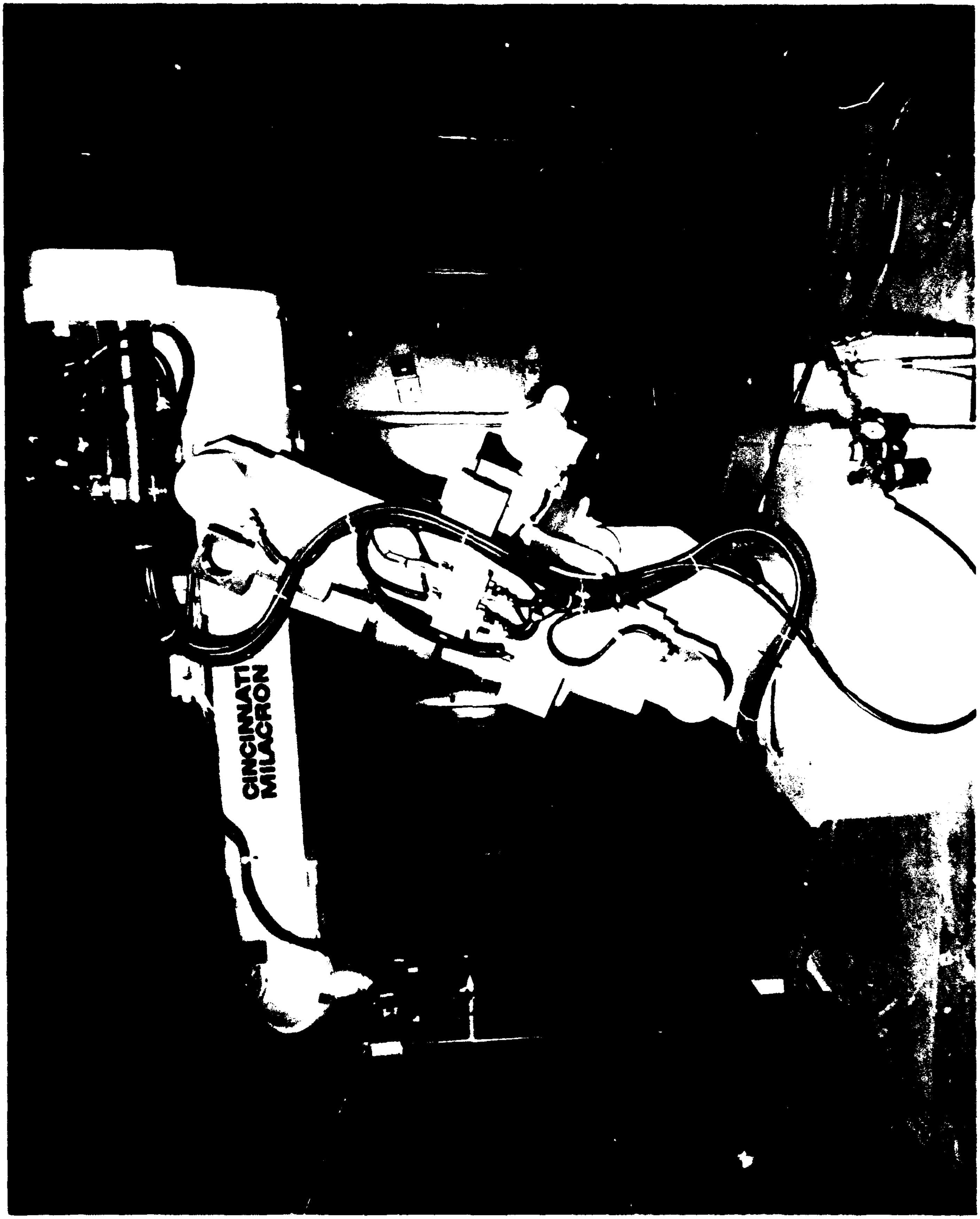
For decoy flare testing an important parameter is the response of the infrared intensity to a high velocity air flow simulating launch of the device from an aircraft. In the AIRTF the air stream simulator is located beneath the floor of the burning chamber with the nozzle protruding through the floor. The air stream is blowing from bottom to top, perpendicular to the floor and the detector line of sight, and directly into the exhaust air system. The flare grain is positioned 53 cm from the end of the nozzle with the longitudinal axis perpendicular to the air flow. Because of the direction of the air flow this makes the longitudinal axis of the grain parallel to the floor. The airstream simulator consists of a 3500 gallon, 100 psi capacity air system with a six inch nozzle which allows various air velocity profiles to be released across the test grain during its burn.

The normal testing sequence is managed by a computerized Automated Test Equipment (ATE) system which also performs the data acquisition and analysis. The data are analyzed in real time and acceptance criteria are imposed as each unit is tested allowing the operator to examine the performance of the test. The test cycle time allows units to be tested at two minute intervals. The ATE allows for calibration of the infrared measurement equipment while in-place in the test tunnel (a true end-to-end calibration). The equipment is housed in an environmentally controlled room which maintains a constant temperature and humidity. This room is semi-mobile to allow the measurement test distance to be changed up to 50 meters.

The ATE interfaces with the Automated Load System which consists of a sequencing conveyor and robot which remove the operator from much of the handling of the items. The ordnance handling which does take place is under a high speed ultraviolet detection deluge system which has a reaction time of 30 milliseconds. There is full closed circuit video coverage of the testing and handling.

Measurements in this facility are generally done using pyroelectric radiometers equipped with appropriate bandpass filters to select the wavelength band of interest. The signals from the radiometers are amplified by a lock-in amplifier and digitized and recorded by an appropriate computer. Radiometer calibration is accomplished using an NIST traceable blackbody. Calibrations are done before and after the test.

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